Cable's Excellent Position in HDTV

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ABSTRACT

The message of this paper is that HDTV will not happen suddenly. Experience shows that developments such as this will take a considerable amount of time. In the mean while we need to take care of our present customers. To do so, cable should deliver the best NTSC available. The need for this is based on the ever-improving performance of consumer electronics equipment.

When we review the mechanisms which cause picture impairments, we realize that there is a limit to what can be accomplished in the receiver. The only alternative is to improve the cable plant. There are a number of cost-effect methods which can be phased into practice in an evolutionary manner. When we examine the technical demands for HDTV carriage, we realize that they are essentially the same as for quality NTSC delivery. Since quality HDTV delivery is mandatory for competitive reasons in the short run, it becomes clear that cable will be ready for HDTV long before consumers are ready for HDTV.

INTRODUCTION

There are three reasons why HDTV is important to the cable industry. First, our friends in the telephone industry continue to say that they are the only ones who will be able to deliver true HDTV to the consumer. They say this must be done digitally and over fiber to the home. This is simply not true. Cable must make it clear that HDTV works well on the kind of coaxial cable systems currently in operation. Fiber backbone strategies and similar approaches make the job easier and the picture even better. But they are technical options, they are not required for cable delivery of HDTV. The second reason for cable involvement in HDTV is that HDTV will be with us for at least fifty years. That alone makes it important. We must be involved in shaping something that will have such a great impact on our future. The third reason is that we need to know how to plan rebuilds and upgrades. Waste can occur in two ways. First we can spend too much too soon. Secondly, if what we build becomes obsolete too soon, it too will have been wasted.

RATIONAL EXPECTATIONS

There was a lot of hype over HDTV and over how quickly it was to sweep across the country. Fortunately, most of that has died down.

Testing of HDTV proponents was originally scheduled to begin in December of 1989. Then it was postponed until June 4, 1990. It is currently hoped that this testing will begin sometime in the Fall of 1990. Nine testing slots were created from the original batch of proponents who qualified. Other proponents have come forth wishing to have slots. It is only human nature to expect that some of those who were tested early in the schedule will have made further inventions and progress and wish to be re-tested.

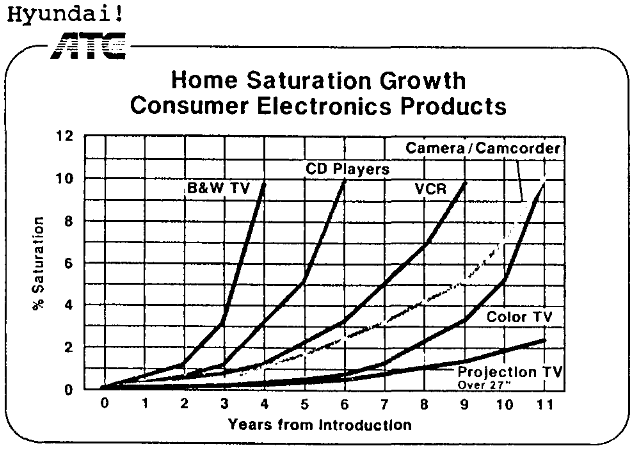
After all of the testing is complete, the advisory committee may need up to a year to digest the data and prepare its conclusions. Then, the FCC will need an additional year to eighteen months to decide.

This all boils down to the conclusion that a terrestrial standard may be available in early 1994. The first HDTV receivers may go on sale in late 1994 or in 1995.

Possible short circuits to this lengthy process would occur if the proponents themselves decide to merge into one system. The David Sarnoff Research Center and Philips Laboratories have agreed to do just that. While this action was necessary, it is by no means sufficient. Nearly all of the proponents need to merge for this short circuit to be successful. That is unlikely for several reasons. Many of the proponents are fundamentally different from each other and cannot merge for technical reasons. There are some very large egos involved which provide political impediments to merger. The "little guys" would cry foul if the big guys joined forces. Finally, there are too many involved in the FCC Advisory Committee to let too much happen without extensive testing.

HBO and MIT both did consumer research which shows that a viewer cannot tell the difference between NTSC and studio quality HDTV when seated more than five time the picture height. The HDTV signal used was not compressed by any of the proponents' systems. It was artifact free. There would be even less difference between NTSC and most proponent systems. Home viewing distance is primarily determined by room size and furniture placement. To satisfy these two constraints, the HDTV receiver must be a large screen device, three to four feet high. HDTV is a large screen phenomena! Large screens of any type, NTSC or HDTV, are expensive. In addition, there are only a limited number of homes which can accommodate a large screen.

History has some useful lessons that can help us project how the HDTV market will be penetrated. It took color TV seven years after introduction to reach one percent penetration. It took color TV eleven years to achieve ten percent penetration. The first black and white television sets cost as much as a compact car of the time. The first color television receivers likewise cost about the same as a compact car. It is reasonable to expect that the first HDTV receivers will cost about as much as a Hyundai!



I believe it is reasonable to predict that HDTV will be at one percent penetration in seven to ten years after introduction. Ten percent penetration will take thirteen to fifteen years after introduction. Thus if introduction takes place in 1994, expect one percent penetration in 2004 and ten percent after 2007. Any more aggressive projections than this demand an explanation. The challenge is this: why would HDTV be more of an improvement over color than color was over black and white? Will this degree of improvement justify the price of a large screen TV? Just as with color, programming will initially be scarce. The broadcast industry is mature and not likely to grow because of HDTV. Its motivation to quickly add programming in an era of less than a few percent receiver penetration will be very low. Certainly, advertisers will not pay more for programing in HDTV if the population of receivers is small.

Another reason for slow penetration of broadcast programming is the very practical problem of new tower construction. It is nearly universally agreed that a new 6 MHz channel will be required for HDTV. This means another transmitter and antenna. But current antenna towers are fully loaded. Few can accommodate another antenna. Since many of these towers are shared, they would have to accommodate several more antennae. The problem of tower construction involves not only cost but getting construction permits. These are difficult to obtain since land is scarce, environmental impact statements need to be filed, and environmental activists' objections overcome. Add to this the growing fear of the potential for electromagnetic radiation to cause cancer, and it is easy to appreciate that spectrum availability is not the only constraint on broadcasters. But this issue must not be slighted. Not only do broadcasters have a spectrum scarcity, more importantly they have a scarcity of <u>quality</u> spectrum. HDTV spectrum must be free of ghosts, co-channel interference, and noise. Otherwise, the HDTV picture will be unacceptable. For these reasons, even if broadcasters could justify the cost, the rush to HDTV transmission simply won't materialize.

GOALS AND OBJECTIVES

Cable should have four principal objectives for HDTV: 1) preserve cable's ability to compete, 2) deliver broadcasters' HDTV signals, 3) serve the NTSC population, and 4) accommodate cable's unique needs. In all of this, cable must find cost-effective solutions.

Clearly, the environment for cable is becoming more competitive. Pre-recorded media, Direct Broadcast Satellite, MMDS, and even digital delivery of video via fiber to the home by the telco's are strong potentials. The most immediate and possibly highest quality delivery may come via baseband prerecorded media with bandwidths of 15 MHz to 20 MHz. We must not be embarrassed when our subscriber turns off his VCR and turns to HBO.

Cable must be able to deliver the HDTV signal broadcasters choose. Broadcast signals are likely to remain very important to our subscribers. It is only good business to deliver what subscribers want. Fortunately, broadcast technologists recognize the importance of cable. While acrimonious rhetoric is employed by some in the upper levels of broadcast and cable management, the engineering community is working together to ensure that things will work from a technical perspective.

Cable has a number of unique needs. These include scrambling, encryption, and addressability. Also, the cable signal must be delivered via satellite to cable headends. The energy in cable signals is important because of the number of signals carried. Unnecessarily high signal energy means amplifiers, laser diodes, and other devices will reach into their non-linear regions of operation and generate undesirable distortions.

Cable should not lose sight of the population of NTSC receivers. There are currently nearly two hundred million NTSC sets and nearly seventy five million NTSC based VCR's. In excess of twenty million new NTSC receivers are added to this population each year. These NTSC receivers have a lengthy life expectancy, typically twelve to fifteen years. Many survive well beyond that. They will be with us for a long time to come.

Given the cost and size of an HDTV receiver, it is likely that for a couple of decades, only one HDTV receiver will exist in most homes. The rest of the home will be sprinkled with NTSC receivers. Thus the technical standard for HDTV must do nothing to impair NTSC receivers.

From a cost perspective, cable must be sure it does not have to raise rates for the NTSC majority to cover the costs of HDTV delivery to a small, less than one percent, opulent minority. This would make for bad business and very bad politics. We believe that this will not be necessary. We believe that cable's best HDTV strategy is to improve our plant to deliver the best NTSC possible. We believe that this will allow HDTV carriage without economic penalty.

IMPROVING NTSC

For decades, NTSC was better than consumer electronics. In that situation, it makes no economic sense to deliver a signal that could not be displayed. Resources are better spent making sure more subscribers have access to signals and have this access at reasonable rates.

But things have changed in the last five years or so. Now consumer electronic equipment can display more quality than the NTSC standard can support. It is now time for the transmission path to catch up to the capability of consumer electronics.

There are two fundamental constraints to the improvement of NTSC: 1) compatibility with existing receivers, and 2) the existing huge population of receivers.

There are two kinds of picture impairments: 1) those due to the NTSC baseband standard, and 2) those due to the manner in which the NTSC modulation structure interacts with the transmission path. The design of the NTSC modulation scheme makes it particularly vulnerable to transmission path problems. A modulation scheme based on modern communications theory would be substantially less subject to transmission path deficiencies. Unfortunately, such a scheme would be incompatible with the existing population of TV receivers.

Baseband impairments include dot crawl and cross color. Dot crawl is the movement of tiny dots along the edges of colored objects. Cross color is the name of the spurious rainbow that appears on monochrome detail such as Johnny Carson's checkered jacket. These are the consequence of the color information being shoehorned into a black and white signal. The two kinds of information get in each others' way. The process for combating this is called "comb filtering". There are a variety of techniques for improving the performance of comb filters. While all make some compromises, smart comb filtering does a very good job of minimizing these artifacts. Other NTSC artifacts include scan line visibility and flickering of bright image areas. These can be minimized by line doublers. They double the number of scan lines by estimating the information not transmitted between the lines. While this does not double the vertical resolution, it does minimize these NTSC artifacts.

Transmission path impairments are much more difficult to deal with. They come in two varieties, coherent and non-coherent. Coherent impairments are more severe. They include ghosts, micro-reflections, cross-modulation, co-channel interference, and beats between carriers. Non-coherent impairments include random noise and impulse noise.

The principal weaknesses of the NTSC standard are its vestigial sideband modulation scheme, the use of simple amplitude modulation, the inter-leaving of the color signal, the separate audio carrier, and the addition of stereo. Vestigial SideBand, VSB, modulation was used to save bandwidth. As a side effect, when the signal is distorted, VSB introduces complexities which are very difficult and expensive to remove. This is the biggest impediment to ghost cancelling. The biggest impediment to cross-modulation and beats is the number of high energy carriers in the signal. The simple method of amplitude modulation makes the NTSC signal vulnerable to noise in the transmission path. These defects are extremely difficult and costly to attack while still remaining compatible with the NTSC standard. The NTSC standard has our hands tied. We have very few options.

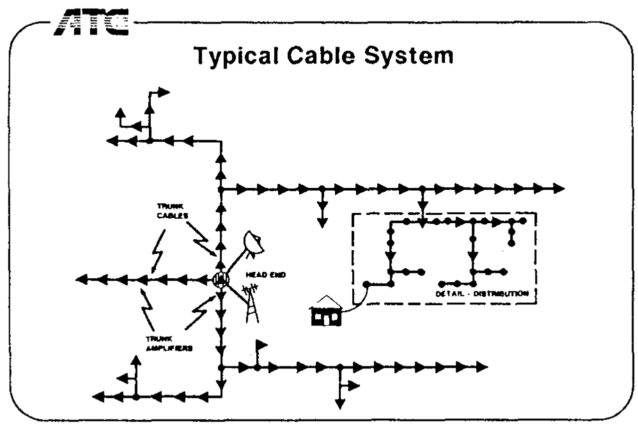
There is one last improvement to NTSC which subscribers demand: more channels. More programing becomes available almost yearly. Subscribers are anxious to have it.

If we insist on remaining compatible with the large population of existing receivers, there is little we can do to improve system performance. After we exhaust the few tools available to us, we must upgrade the plant itself. Fortunately, this can be done in a cost effective and evolutionary manner.

Two of the many techniques for improving NTSC which directly support a strategy for HDTV are the fiber backbone coupled with amplifier upgrades and super distribution. The first of these techniques yields more channels and less noise while the second reduces miro-reflections and non-linearities.

In the typical cable system, long cascades of amplifiers build up noise and limit bandwidth. While the cable itself is often capable of transmitting one gigaHertz and more, the amplifier cascades are limited to 650 MHz or so. In addition, the long cascades are a serious reliability hazard.

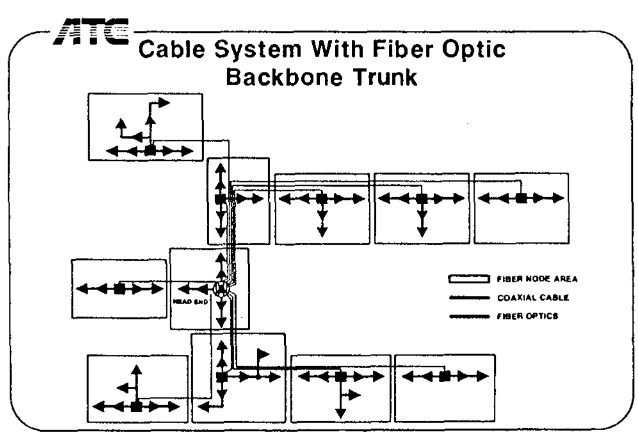
The fiber backbone approach breaks the cable system into a multitude of much smaller cable systems with amplifier cascades limited to four to six amplifiers. Each of these small cable systems is fed with a fiber link to the headend. The advantages include significantly lowered vulnerability to amplifier outages, reduced bandwith restrictions and noise build up due to amplifiers in series, and greatly reduced ingress. The latter effect makes two-way cable practical. A major attraction of the fiber backbone is that its implementation cost is low. Fiber is "over lashed" onto the existing trunk plant. The in-place cable is broken into segments and used for the small scale cable systems. Some of the amplifiers are reversed in direction. Nothing is wasted.



Typical Cable System

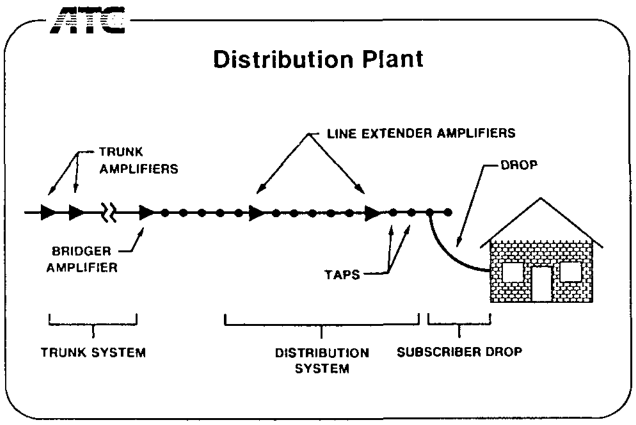
In the typical cable system, 10% of the cable footage is in the trunk, 40% of the footage is in the tapped distribution, and 50% is in the drops. The cost effectiveness of the fiber backbone technique stems form the fact that it involves only 10% of the plant footage. In some design studies, the cost of implementing this upgrade came to less than $25 per subscriber.

The fiber backbone effectively cures most of the ills of the trunk part of the plant. This improves NTSC delivery as well as prepares the trunk plant for HDTV.



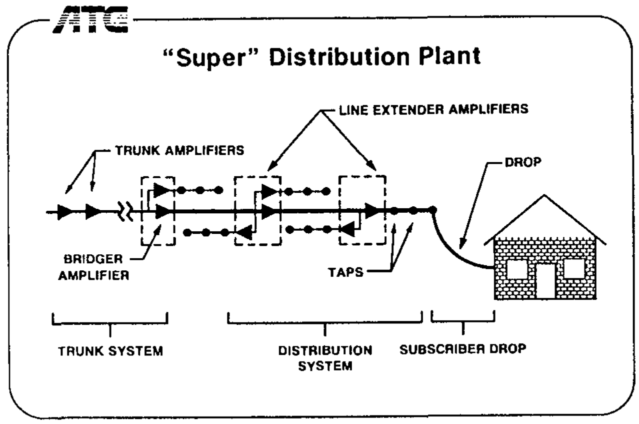
Cable System With Fiber Optic Backbone Trunk

If we now turn our attention to the distribution plant, we find that we must run higher signal levels to support the tapping of energy to serve drops to customers. The higher signal levels mean that we begin to reach into non-linear areas of the amplifiers' operating characteristic. Non-linear distortion builds up. In addition, the taps are not perfectly impedance matched to the cable. Consequently, the signal is reflected back and forth between the taps resulting in a smearing of the picture. This phenomena is called "micro-reflection" for two reasons. The strength of the reflections is low and the time delay of the reflections is short.



Rogers Cable of Canada has suggested the answer to these difficulties. They have called their technique "Super Distribution". In one form of its implementation, line extender amplifiers are structured to have up to three hybrid amplifier chips. One feeds the next line extender amplifier, one feeds half of the taps back to the previous line extender, and the third feeds half of the taps to the next line extender. The existing tapped feeder cable is cut in half between line extenders. New, untapped cable is over lashed to connect line extenders. The consequences are that the signal level between amplifiers is lower since that cable is not tapped. The signal level on the tapped runs is lower because they are shorter. Non-linearities are reduced and they do not build up as in the previous structure. Also, signal leakage may be less of a problem because of the lower signal levels. In addition, the number of taps in series in any cable is drastically reduced thereby reducing the amount of micro-reflections experienced by any one subscriber. This technique effectively cures the ills of distribution portion of the plant. Rogers estimates the cost of this upgrade to be less than $25 per subscriber.

With fewer amplifiers in series, the constraints on their design and operation are reduced. Higher bandwidths become practical.



Recently, Dave Pangrac of ATC has developed an extension of the fiber backbone approach which takes fiber farther into the plant. In one version, passive splitters are added to the fiber run from the headend. Then shorter runs into the neighborhood bring the optical plant closer to the home. Even fewer amplifiers are interposed between the subscriber and the headend. In another implementation, low cost lasers are used as repeaters to feed the branches at the end of the trunk run. The potential of optical amplifiers promises to yield further evolution of this technique.

CONCLUSION

If the assumptions on HDTV timing are correct and if the assumptions for the need of better NTSC in the shorter term are correct, cable will be ready for HDTV long before consumers are ready to spend the money these new receivers will demand. This will happen in an evolutionary manner over many years. It will be a cost effective approach which will generate compensating revenues and economies of operation.

THE AUTHOR

Dr. Ciciora is Vice President of Technology at American Television &Communications, ATC, in Stamford Connecticut. Walt joined ATC in December of 1982 as Vice President of Research and Development. Prior to that he was with Zenith Electronics Corporation since 1965, He was Director of Sales and Marketing, Cable Products, from 1981 to 1982.

Earlier at Zenith he was Manager, Electronic System Research and Development specializing in Teletext, Videotext and Video Signal Processing with emphasis on digital television technology and ghost canceling for television systems.

He has nine patents issued. He has presented over seventy papers and published about thirty, two of which have received awards from the IEEE. Walt writes a monthly column titled "Ciciora's Page" for Communications Engineering and Design magazine.

He is currently chairman of the National Cable Television Association, NCTA Engineering Committee, Chairman of the Technical Advisory Committee of Cable Labs, and President of the IEEE Consumer Electronics Society. He is a past chairman of the IEEE International Conference on Consumer Electronics. Walt is a Fellow of the IEEE, a Fellow of the Society of Motion Picture and Television Engineers, and a senior member of the Society of Cable Television Engineers. Other memberships include Tau Beta Pi, Eta Kappa Nu, and Beta Gamma Sigma. He served on several industry standard-setting committees. Current interests center on competitive technology, the consumer electronic interface with cable, and HDTV.

Walt received the 1987 NCTA Vanguard Award for Science and Technology .

Walt has a Ph.D. in Electrical Engineering from Illinois Institute of Technology dated 1969. The BSEE and MSEE are also from IIT. He received an MBA fro the University of Chicago in 1979. He has taught Electrical Engineering in the evening division of IIT for seven years.

Hobbies include reading, wood working, photography, skiing, and a hope to someday become more active in amateur radio (WB9FPW).